# Space Weather Technical Forecast

Issued on Saturday, 25 December 2021 at 01:29 Local

**This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales**

**Space Weather Forecast Headline: Slight chance of G1/Minor Storms on 27 December. Chance of M-class flares (R1/R2 Radio Blackout), with slight chance of X-class (R3 Radio Blackout).**

**Analysis of Space Weather Activity over past 24 hours**

**Solar Activity:** Solar activity has been low over the past 24 hours, with numerous C-class flares observed. Flare activity has been mainly concentrated in the southwest quadrant from 2907 (Ehi/Beta) and 2908 (Bxo/Beta). 2907 has continued to develop and now has a number of intermediate spots between the two main penumbra regions. 2908 has declined despite some recent flaring. 2917 (Dro/beta) has also produced a C7.4 flare in the last 24 hours and continues to develop. 2918 (Dai/Beta) is developing in bursts and has the potential to produce significant flares. All the other regions are either benign, stable or declining in complexity.
A CME was observed leaving the Sun close to the region of 2907 or 2908 at 24/1130UTC, but preliminary modelling suggests that this is not Earth-directed.

**Solar Wind / Geomagnetic Activity:** A CME from 20th December was forecast to arrive by 24 December, but now appears to have missed the earth. Solar wind speeds as observed by DSCOVR at L1 have been slightly elevated under the waning influence of coronal hole 35. Density has been around average with little change. Interplanetary magnetic field strength was weak, with the north-south component also varying weakly. Phi angle has been predominantly negative (towards the Sun). Geomagnetic activity was Quiet to Unsettled (Kp 0-3).

**Energetic Particles / Solar Radiation:** The high energy proton flux (greater than 10 MeV) remained at background levels. The high energy electron flux (greater than 2 MeV) was high between 24/0855UTC and 24/2020UTC, reaching a peak of 2.02e3pfu at 24/1715UTC. The associated 24-hour integrated fluence started above the Active threshold, but has declined through the 24 hour period to fall to 9.21e7 integrated pfu by 24/0000UTC.

**Four-Day Space Weather Forecast Summary**

**Solar Activity:** Low solar activity is forecast throughout the period, with a chance of M-class flares and a slight chance of X-class flares. This is due to four active regions with significant flare potential, with three of these in the eastern hemisphere.

**Solar Wind / Geomagnetic Activity:** There are two potentially Earth-directed CMEs forecast, with the 20 December CME now removed from the forecast. These two CMEs left the Sun on 21 and 22 December respectively and could glance the Earth on 26 or 27 December. A CME which left the Sun on 24 December is not forecast to affect the Earth. The high speed stream from coronal hole 37 is forecast to connect with the Earth on 27 December, with expected speeds of around 500km/s. Mainly Quiet geomagnetic activity is forecast through days 1 and 2, with a chance of Active and a slight chance of G1/Minor Storms on day 3 due to the coronal hole effects.

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**Energetic Particles / Solar Radiation:** The high energy (greater than 10 MeV) proton flux is expected to remain at background levels and below the S1 level, although there is a slight chance for some increased flux from any significant flare activity. High energy electron flux (greater than 2MeV) levels are forecast to fall to increasingly moderate levels through the next two days, with a more significant fall to background on day 3 following the forecast heightened geomagnetic activity. Electron fluence is expected to follow a declining trend and remain below the Active (1e8 integrated pfu) threshold.

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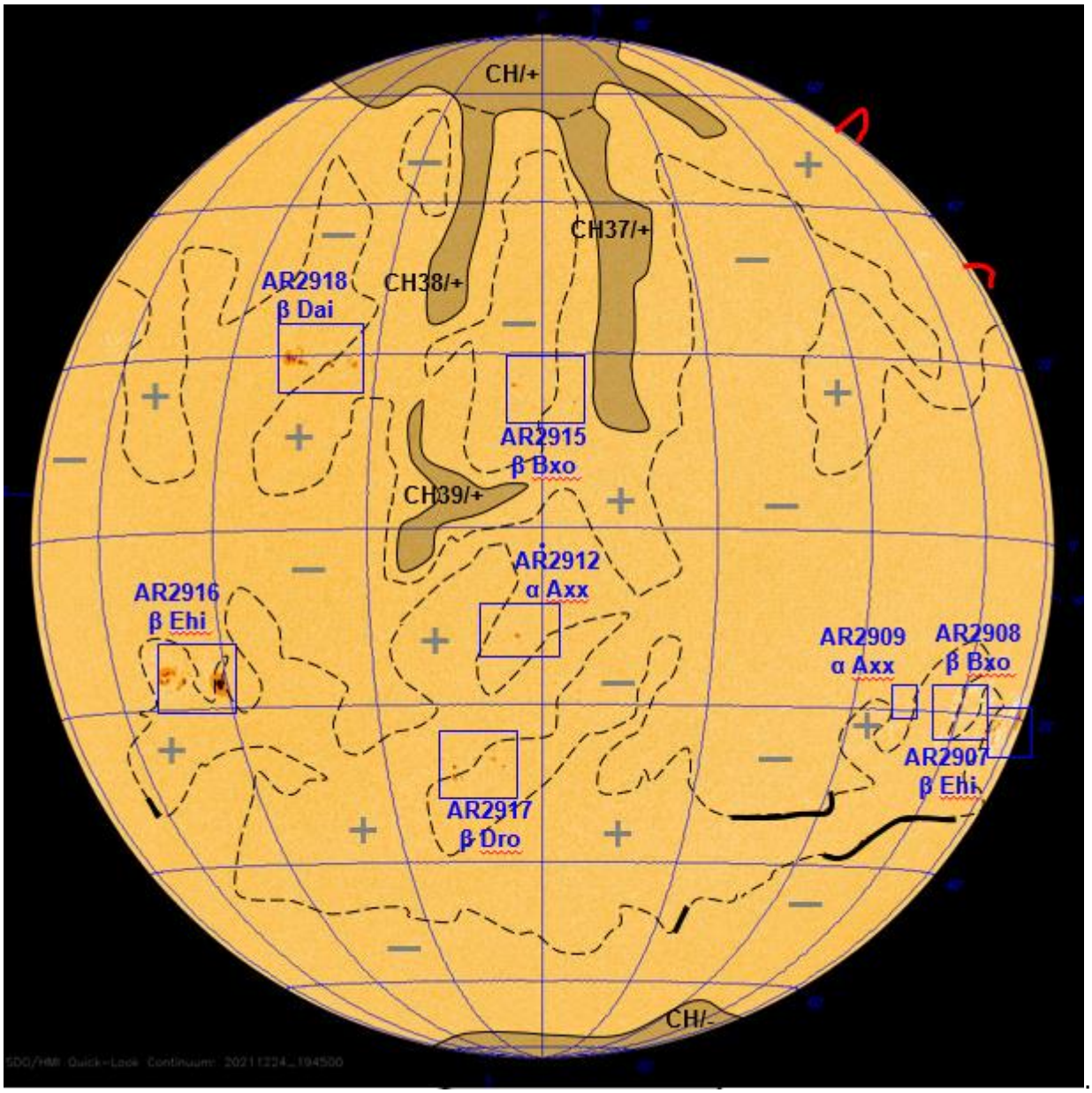
**Figure 1. Solar Analysis Valid 24/2000UTC.**




**Key:** Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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## Geomagnetic Storms:

A CME which left the Sun on 20 December was due to arrive either during 23 or 24 December, but with low confidence. No effects have been observed from a potential CME arrival, therefore this is now considered to have missed the earth. Three further CMEs are currently modelled by Enlil. The first two, which left the Sun on 21 and 22 December respectively, may glance the Earth on 26 or 27 December. However, as both were relatively narrow features, there is low confidence in this aspect of the forecast and they could miss entirely. The remaining CME left the Sun from the southwest quadrant early on 24 December and preliminary analysis suggests that this will miss the Earth.

Coronal hole 37 is forecast to connect with the Earth on 27 December. This is a recurrent feature which produced speeds of around 500km/s on the previous rotation. Similar speeds are assumed on this rotation, as the feature has not yet been detected at STEREO A. If the speeds from the hole are slightly higher then an earlier arrival is possible.

Geomagnetic activity is expected to be mainly Quiet on day 1 (25 December) on the assumption that the 20 December CME has missed the Earth. Mainly Quiet conditions are then expected through day 2, with a chance of Active and a slight chance of G1/Minor Storm intervals later in the day and on day 3, due to the anticipated connection with the high speed stream from coronal hole 37. A smaller risk of G1/Minor Storm conditions are maintained into day 4.

| Geo-Magnetic Storm Probability (Exceedance) | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| Minor or Moderate | G1 to G2 | No | 5 | 10 | 20 | 10 |
| Strong | G3 | No | 1 | 1 | 1 | 1 |
| Severe | G4 | No | 1 | 1 | 1 | 1 |
| Extreme | G5 | No | 1 | 1 | 1 | 1 |

## Geomagnetic Activity - Earthbound Coronal Mass Ejections

| Date/time 21.5R (UTC) | Halo: Full or Partial | Source | Source Location | Estimated Speed | Estimated Arrival Time | Comments |
|---|---|---|---|---|---|---|
| 22/0726 | Partial | 2908 | SW limb | 475 | 27/1300 | Glancing shock |
| 22/1735 | Partial | 2908 | SW limb | 319 | 27/1300 | Glancing shock. |

**Figure 2: MOSWOC Enlil forecast**

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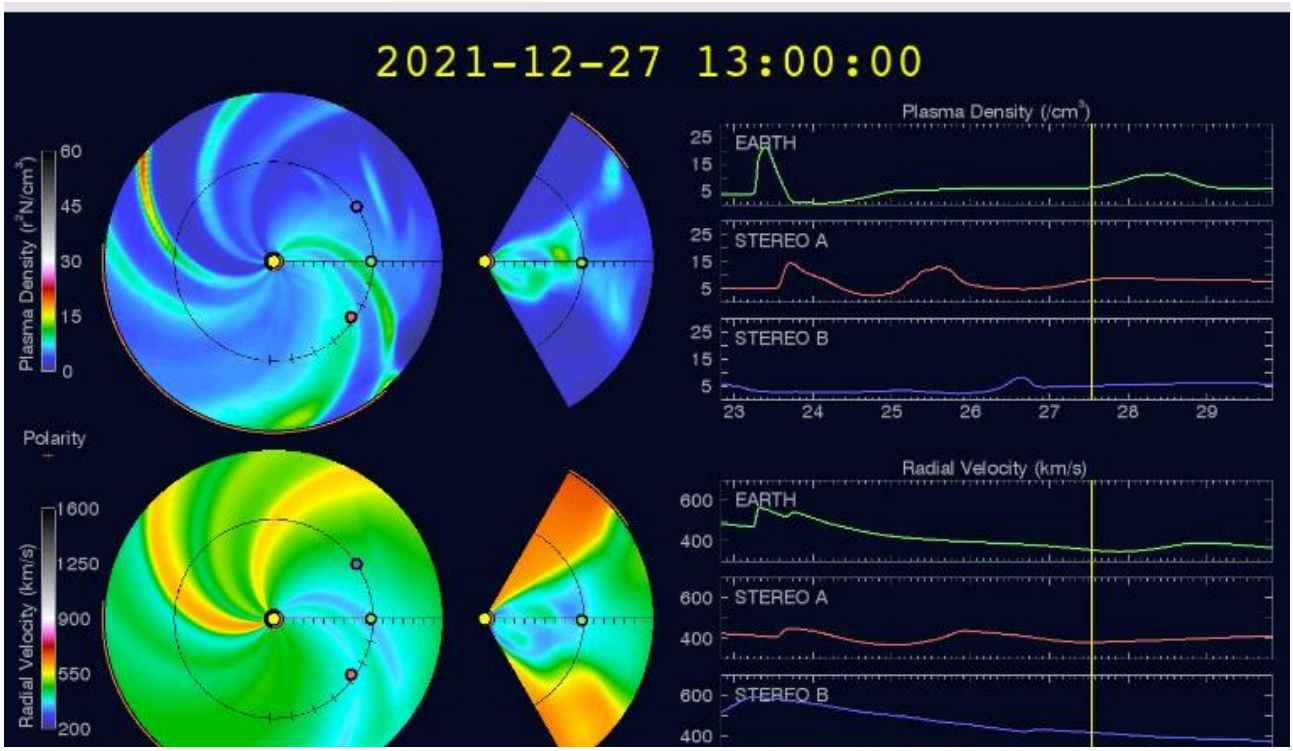
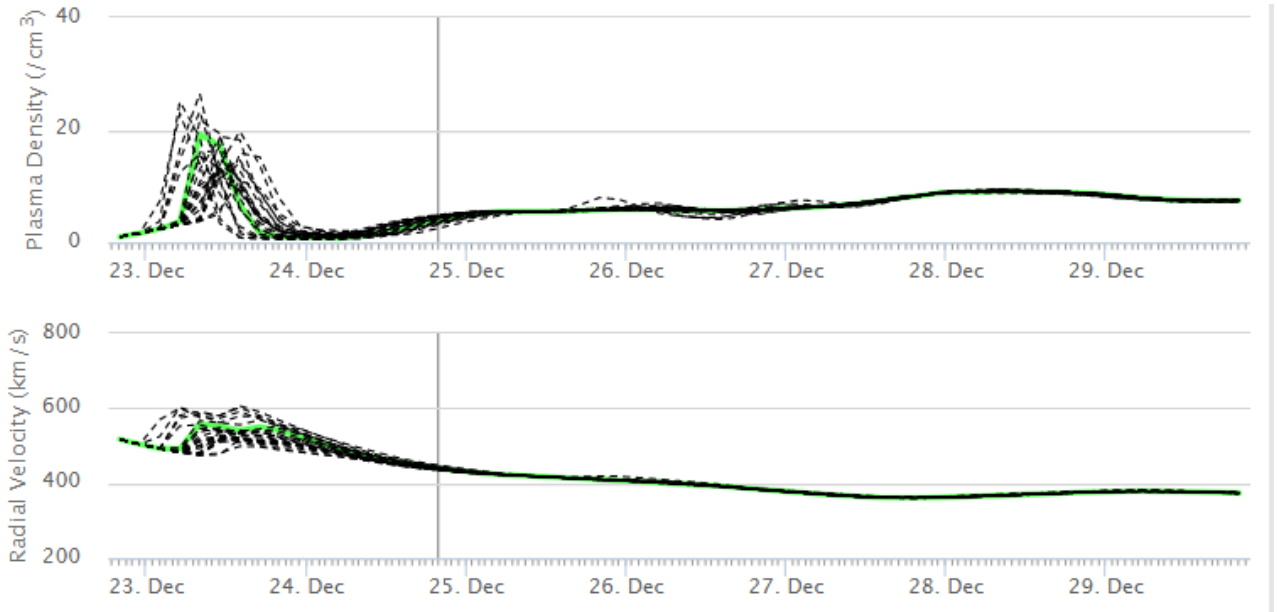



**Figure 3: MOSWOC Enlil ensemble, showing likely arrival times of glancing CMEs**

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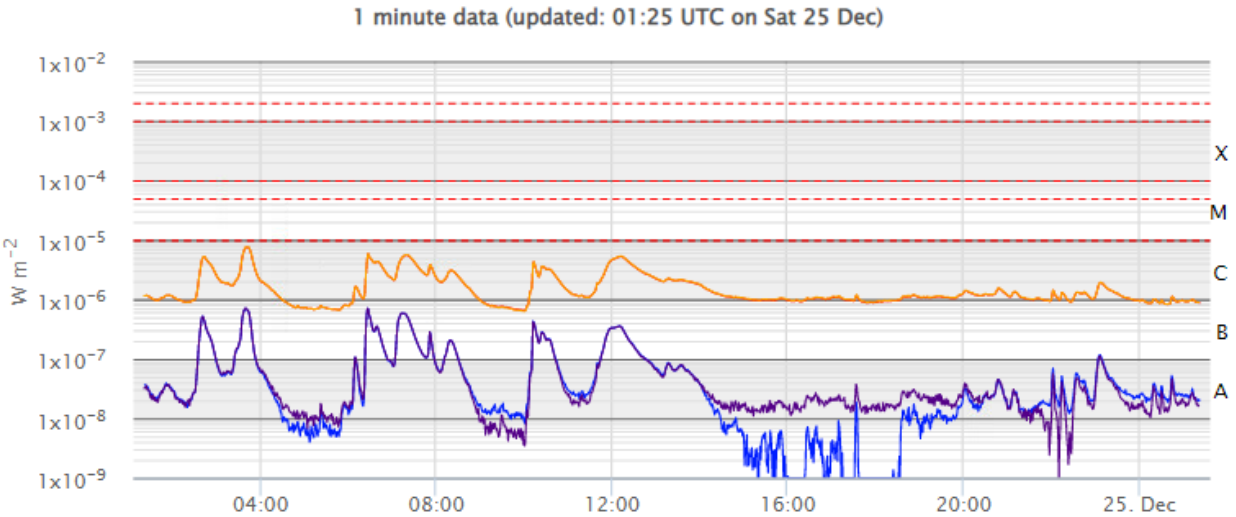
**Radio Blackouts - X-Ray Flares:**
There are 8 sunspot regions on the visible disc. Two of these contribute the most to the overall flare risk. 2907 is the most mature of these regions and is now close to the southwestern limb and will rotate across the horizon in the next 36 hours. This is classified as Ehi/Beta and has continue to evolve with a number of intermediate spots developing and may have been responsible for a recent CME. 2916 in the southeast quadrant is also classified as Ehi/Beta and presents an elevated flare risk for the next four days and is seeing developing in the trailer spots.

Two regions have continued to develop over the last 24 hours. 2917 (Dro/Beta) which has produced a C7.4 flare and 2918 which exhibits bursts of growth followed by briefer stable periods. The remaining regions are either stable, benign or declining regions.

Overall, given that a number of the developing regions are in the eastern hemisphere, a chance of M-class flares is maintained through the next four days.

| X Ray Flares<br>Probability | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC)<br>(%) | Day 2 (00-24 UTC)<br>(%) | Day 3 (00-24 UTC)<br>(%) | Day 4 (00-24 UTC)<br>(%) |
|---|---|---|---|---|---|---|
| **Active** | **R1-R2 M Class** | No | 40 | 40 | 30 | 30 |
| **Very Active** | **R3 to R5 X Class** | No | 15 | 15 | 5 | 5 |

**Figure 4: GOES 16 X-ray flux**

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**Solar Radiation Storms - (High Energy Protons):**
The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently at background levels and expected to persist at these levels. 2907 is considered to be the most likely region as a source for any proton storms and despite rotating across the horizon on day 2, any storms could be carried to Earth in the Parker spiral.

| Radiation Storms Probability (Exceedance) | Level ($cm^{-2}$ $sr^{-1}$ $s^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| **Active** | **≥ S1** | No | 5 | 5 | 5 | 1 |
| **Very Active** | **≥ S3 *** | No | 1 | 1 | 1 | 1 |

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

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## High Energy Electrons Event (≥ 2MeV):

The high energy electron flux has been at mainly moderate to high levels due to the input from the high speed stream of coronal hole 35. As this high speed stream declines, the diurnal maximum is expected to decline on days 1 and 2, with high levels increasingly unlikely. A more sustained drop in electron flux is expected on day 3 (27 December) due to the connection with the high speed stream from coronal hole 37. The increase in geomagnetic activity will result in a redistribution of the electrons within the belts, with the strength of the high speed stream likely to distort the belts out of GEO. A minor recovery in counts may develop through day 4.

Electron fluence values are following a declining trend, which is reflected in the MOSWOC REFM model. This pattern is accepted through the forecast period, with a decreasing chance of exceeding the Active threshold.

| GEO Electron Environment | Level ($cm^{-2}$ $sr^{-1}$ $day^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) | Day 2 (00-24 UTC) | Day 3 (00-24 UTC) | Day 4 (00-24 UTC) |
|---|---|---|---|---|---|---|
| Probability (Exceedance) | | | (%) | (%) | (%) | (%) |
| Active | ≥ 2 MeV ≥ $1x10^8$ | Yes | 50 | 20 | 10 | 10 |
| Very Active | ≥ 2 MeV ≥ $1x10^9$ | No | 1 | 1 | 1 | 1 |

**Figure 5: GOES 16 electron flux**

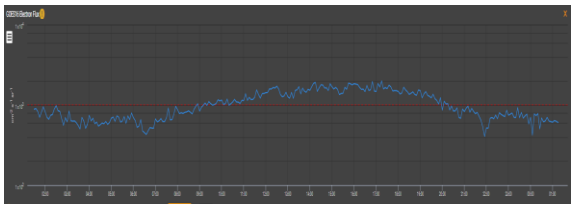
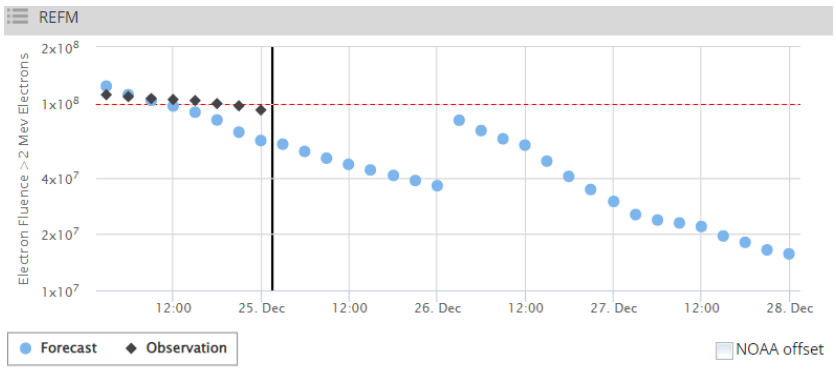


**Figure 6: MOSWOC REFM model showing actual and forecast decline in electron fluence**

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